



DISCRETE CALCULUS ANALYSIS OF POVERTY DYNAMICS IN JAYAPURA REGENCY, 2017-2024, BASED ON SDG GOAL 1

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Abstract :

Poverty in Jayapura Regency, one of the buffer areas of Papua Province's capital region, is a key challenge in achieving the Sustainable Development Goals (SDGs) Goal 1: No Poverty. This study aims to analyze the rate of change and dynamics of poverty in Jayapura Regency for the period 2017-2024 and project it to 2030 using a discrete calculus or finite-difference approach. The research method is quantitative descriptive with secondary data on the percentage of the poor population from the Central Statistics Agency (BPS). The analysis was conducted by calculating the first derivative (rate of change) and the second derivative (acceleration/deceleration) discretely. The results show that the poverty rate declined from 13.01% (2017) to 11.60% (2024). However, derivative analysis reveals a significant deceleration phase in the 2022-2024 period, culminating in a reversal to a positive rate of change (+0.15 percentage points) in 2024. This critical finding suggests that the post-pandemic momentum for poverty reduction has weakened and is beginning to reverse. Simple linear projections up to 2030 indicate that the SDG target for eliminating extreme poverty is at risk of being missed without significant policy acceleration. The differential calculus approach has proven effective as an early detection tool for detecting changes in momentum that are not always visible from static annual data.

Keywords : Poverty rate; discrete calculus; Jayapura Regency; SDG Goal 1; rate of change

INTRODUCTION

Poverty is a multidimensional issue and remains a global and national priority, reflected as Goal 1 of the Sustainable Development Goals (SDGs). Conceptually, poverty is not only understood as limited income, but also as limited capabilities, vulnerability to shocks, and cross-dimensional deprivation that can be measured through headcount, depth, severity, and multidimensional approaches (Sen, 1976; Foster, Greer, & Thorbecke, 1984; Alkire & Foster, 2011). In the context of the 2030 Agenda, eradicating extreme poverty requires not only a decrease in annual figures, but also consistent acceleration so that the trajectory of regional achievements remains in line with the SDG targets (Ravallion, Chen, & Sangraula, 2009; Central Bureau of Statistics, 2024; United Nations Department of Economic and Social Affairs [UN DESA], 2024).

Jayapura Regency holds a strategic position as a buffer zone for the provincial capital, with characteristics of coastal, urban (Sentani), and inland areas. This geographic diversity is important because studies in Indonesia show that poverty reduction is influenced by location, the composition of growth sectors, the quality of human resources, access to basic services, and



heterogeneity between regions (Akita, 2002; Suryahadi, Suryadarma, & Sumarto, 2009; De Silva & Sumarto, 2015). For Papua, empirical evidence also shows that district/city poverty is heterogeneous and related to economic growth, human development, territorial status, and regional fiscal capacity (Panjawa, 2020; Pratiwi & Joshi, 2025). Therefore, policy analysis that focuses solely on static annual poverty figures risks ignoring the speed, direction, and momentum of change, which are crucial for the effectiveness of interventions.

The novelty of this study lies in the application of discrete differential calculus, namely the use of first and second derivatives on time series poverty data from Jayapura Regency. The first derivative is used to calculate the annual rate of change, while the second derivative is used to calculate the change in momentum, namely whether poverty reduction is accelerating, slowing, stagnating, or reversing. The finite difference-based approach is relevant for discrete annual data, but it also requires careful interpretation because derivative estimates on observational data can be sensitive to short-term fluctuations (Savitzky & Golay, 1964; Chartrand, 2011; Purcell, Rigdon, & Varberg, 2019).

RESEARCH METHOD

This study employed a descriptive quantitative method with a mathematical approach of discrete discrete calculus. The data were obtained from official secondary sources published by the Central Statistics Agency (BPS) of Jayapura Regency, especially the publication Jayapura Regency in Figures 2025 which contains the poverty line, the number of poor people, and the percentage of poor people for the period 2017-2024 (Central Statistics Agency of Jayapura Regency, 2025). The main research variable is the percentage of the population living in poverty, which is denoted as a function of time $P(t)$. The use of the percentage of poor people indicator is in line with the tradition of macro poverty measurement, although its interpretation needs to be complemented by an understanding of the poverty line, vulnerability dynamics, and regional inequality (Pradhan, Suryahadi, Sumarto, & Pritchett, 2001; Ravallion et al., 2009; Dartanto & Nurkholis, 2013). The data analysis was conducted in several stages:

1. Descriptive Analysis: Constructing a time-series function $P(t)$ based on BPS data and describing the poverty rate trend in Jayapura Regency 2017-2024.
2. Rate of Change Analysis (First Derivative): Calculating the discrete first derivative to measure the annual rate of change in percentage points, with the formula

$$P'(t) = P(t + 1) - P(t)$$

3. Momentum Analysis (Second Derivative Calculating the discrete second derivative to identify the acceleration or deceleration of the rate of change, with the formula:

$$P''(t) = P'(t + 1) - P'(t)$$

4. Projection: Performs a simple linear projection to 2030 based on the average historical rate of change and the current rate of change. This projection is intended to illustrate policy implications, not a deterministic

forecast.

Interpretation is based on the following conditions: a negative rate of $P'(t) < 0$ change indicates a decrease in poverty (improving conditions), while a positive rate of change $P''(t) < 0$ indicates an increase in poverty. A negative second derivative indicates an accelerating decline (accelerating improvement), while a positive second derivative $P''(t) > 0$ indicates a slowing decline or even an increase.

FINDINGS AND DISCUSSION

1. Overview of Poverty Data

The following is data on the poverty line and percentage of poor people based on data from the BPS Jayapura Regency for the 2017-2024 period in Jayapura Regency, Papua Province as presented in Table 1.

Table 1. Poverty Line, Number, and Percentage of Poor Population in Jayapura Regency, 2017-2024

No	Year	Poverty Line	Number of Poor People (Thousands)	Percentage of Poor Population
1	2017	489,519	16.31	13.01
2	2018	489,932	17.19	13.44
3	2019	549,489	17.79	13.13
4	2020	589,521	16.61	12.44
5	2021	628,845	16.61	12.44
6	2022	651,581	15.43	11.94
7	2023	706,549	14.91	11.45
8	2024	729,234	15.21	11.60

Source: Jayapura Regency Central Statistics Agency in Figures 2025

2. Data Analysis

Based on data from the Statistics Indonesia (BPS) of Jayapura Regency for the 2017-2024 period, the poverty rate shows a general downward trend, from 13.01% in 2017 to 11.60% in 2024. However, behind this downward trend, there are important fluctuating dynamics. Literature on poverty dynamics in Indonesia shows that aggregate changes often hide household mobility in and out of poverty, vulnerability to shocks, and differences in response between regions (Skoufias & Suryahadi, 2000; Suryahadi & Sumarto, 2003; Suryahadi, Widyanti, & Sumarto, 2003; Dartanto & Nurkholis, 2013). Table 2 presents complete data on the percentage of the poor population along with its annual rate of change.

Table 2. Poverty Level and Rate of Change in Jayapura Regency, 2017–2024

Year	Poverty Rate $P(t)$ (%)	Rate of Change $P'(t)$ (%)	Interpretation of Rate
2017	13.01	-	-
2018	13.44	+0.43	Increase
2019	13.13	-0.31	Decrease
2020	12.44	-0.69	Sharp Decrease
2021	12.44	0.00	Stagnant
2022	11.94	-0.50	Decrease
2023	11.45	-0.49	Decrease
2024	11.60	+0.15	Warning Sign atau Concerning Increase

Source: BPS, processed (2025)

3. Analysis of Rate of Change and Momentum (First and Second Derivatives)

The first derivative analysis of $P'(t)$ confirms that poverty reduction in Jayapura Regency is not linear. There was an increase at the beginning of the period (2017-2018), followed by a significant decline in 2019-2020, reaching -0.69 percentage points. This is the fastest rate of decline throughout the observation period. However, a warning signal emerged when the rate of decline began to slow in 2022-2023, and reversed to an increase of +0.15 percentage points in 2024. In reading discrete time series, a change in sign from negative to positive is an important signal because it indicates a possible change in the direction of the process, although it still needs to be linked to the economic and policy context (Savitzky & Golay, 1964; Chartrand, 2011). To understand this dynamic more deeply, the second derivative analysis of $P''(t)$ is crucial. The results are presented in Table 3.

Table 3. Analysis of Acceleration/Deceleration (Second Derivative) of Poverty in Jayapura Regency

Period	$P'(t + 1)$	$P'(t)$	$P''(t)$	Momentum Interpretation
2018–2019	-0.31	+0.43	-0.74	Accelerated Decline (Accelerated Decrease)
2019–2020	-0.69	-0.31	-0.38	Accelerated Decline
2020–2021	0.00	-0.69	+0.69	Significant Slowdown (Deceleration)
2021–2022	-0.50	0.00	-0.50	Accelerated Reduction (Momentum Recovery)
2022–2023	-0.49	-0.50	+0.01	Mild Slowdown (Approaching Stagnation)
2023–2024	+0.15	-0.49	+0.64	Accelerated Increase (Critical Condition)

Source: Analysis Results (2025)

Based on the results of the analysis of the data in Table 3, it provides in-depth insights, namely:

1. Positive Momentum (2018–2020): This period is characterized by the value $P''(t)$ negative, meaning poverty reduction is occurring at an increasingly rapid rate. This is the period of strongest poverty reduction in Jayapura Regency.
2. First Critical Point (2020-2021): A major deceleration (+0.69) occurred. The rate of decline, which was initially rapid (-0.69), then slowed drastically

until it stagnated (0.00). This finding can be interpreted in conjunction with literature showing that the economic crisis and the COVID-19 pandemic increased the risk of poverty through reduced income, job disruptions, and limited household consumption (Suryahadi, Sumarto, & Pritchett, 2003; Suryahadi, Al Izzati, & Suryadarma, 2020; Suryahadi, Al Izzati, & Yumna, 2021).

3. Second Critical Point (2023-2024): This is the most concerning finding. There was an accelerated increase of +0.64. This value indicates that the rate of change not only reversed from negative to positive, but also increased very rapidly. In one year, almost half of the decline achieved in the previous year (-0.49 points) was erased by an increase of +0.15 points. Within the SDGs monitoring framework, this pattern is important to treat as an early warning signal because it could shift the achievement trajectory away from the 2030 target (UN DESA, 2024; Yusuf, Anna, Komarulzaman, & Sumner, 2023).

4. Interpretation in the Context of SDGs and 2025-2030 Projections

The poverty reduction in Jayapura Regency from 13.01% (2017) to 11.60% (2024) represents progress, but the average rate remains low. The total decline of 1.41 percentage points over seven years equates to an average of approximately -0.20 percentage points per year. The pro-poor growth literature in Indonesia emphasizes that economic growth does not automatically reduce poverty equally; the distribution of benefits, sector composition, quality of basic services, and regional characteristics are crucial factors in determining the success of poverty reduction (Suryahadi et al., 2009; Suryahadi, Hadiwidjaja, & Sumarto, 2012; De Silva & Sumarto, 2014; Hill, 2020). At this rate, the target of eradicating extreme poverty by 2030 will be very difficult to achieve without significant policy acceleration. Even more worrying is the possibility of a reversal of the trend by 2024. To illustrate the implications, here are simple projections using two scenarios based on current rates of change.

Table 4. Projection of Poverty Level in Jayapura Regency 2025-2030

Year	Pessimistic Scenario(2023-2024 rate: +0.15)	Optimistic Scenario(Average 2017-2024: -0.20)
2024	11.60%	11.60%
2025	11.75%	11.40%
2026	11.90%	11.20%
2027	12.05%	11.00%
2028	12.20%	10.80%
2029	12.35%	10.60%
2030	12.50%	10.40%

Source: Author's Projection (2025)

Note: The pessimistic scenario assumes a continued rate of increase of +0.15 points/year. The optimistic scenario assumes the government successfully returns the rate to the historical average of -0.20 points/year.

These projections indicate an unfavorable trajectory picture if the upward trend observed in 2024 is not immediately addressed. The Pessimistic Scenario suggests that by 2030, the poverty rate will actually increase to 12.50%, falling back to near pre 2020 – 2023 levels. Even in the Optimistic Scenario, which

assumes a recovery to the historical average rate of decline, the poverty rate in 2030 will still be around 10.40%. This means that the current trajectory is insufficient to support the SDGs agenda without more targeted policies, particularly for vulnerable households, areas with limited access to basic services, and economic sectors that employ poor workers (Bazzi, Sumarto, & Suryahadi, 2015; Sparrow, Suryahadi, & Widyanti, 2013; Pratiwi & Joshi, 2025).

The application of differential calculus to Jayapura Regency poverty data successfully identified a critical turning point in 2024. This finding has important policy implications. If stakeholders were only looking at static data (11.45% in 2023 vs. 11.60% in 2024), a 0.15-point increase might be considered a small fluctuation. However, a second derivative analysis shows that the increase was accompanied by a positive acceleration (+0.64), making it more appropriately treated as a change in momentum. This approach reinforces the need for monitoring based on rates and acceleration, rather than just annual level achievements.

The underlying causes of this reversal require further investigation using micro-household data and inter-district spatial data. However, based on the Indonesian poverty literature and the Papuan context, the following external and internal factors may be contributing factors:

1. Inflationary pressures and the cost of living: Rising prices for food, energy, transportation, and basic necessities have the potential to depress the purchasing power of poor and vulnerable households. Poor households generally have limited room to adjust consumption, so price shocks can quickly be reflected in increases in poverty (Skoufias & Suryahadi, 2000; Dartanto & Nurkholis, 2013).
2. Non-inclusive local economic transformation: Economic growth in the Sentani area and its surroundings does not automatically reduce poverty if its benefits are concentrated in certain sectors or groups. Empirical evidence from Indonesia shows that the effects of growth on poverty are highly dependent on the sector, location, and distribution of growth benefits (Suryahadi et al., 2009; De Silva & Sumarto, 2014).
3. Social protection and household resilience: Post-pandemic, the effectiveness of social assistance, health insurance, and cash transfers will significantly determine the ability of poor households to maintain consumption. Indonesian studies show that targeting accuracy, disbursement timing, and the design of social protection programs influence welfare and poverty dynamics (Sumarto, Suryahadi, & Widyanti, 2005; Sparrow et al., 2013; Bazzi et al., 2015).

This study's limitations lie in the use of aggregate district data, which does not capture spatial disparities between districts and poverty mobility at the household level. Therefore, the discrete differential calculus approach used in this article is more appropriately positioned as an early warning system. For further analysis, this analysis needs to be combined with microdata, spatial mapping, small area estimation, or spatial machine learning modeling to identify poverty hotspots more precisely (Gonzales Martinez & Cooray, 2025; Panjawa,

2020; Pratiwi & Joshi, 2025).

CONCLUSION

Based on a differential calculus analysis of poverty data in Jayapura Regency for the 2017-2024 period, this study draws three main conclusions. First, Jayapura Regency has shown progress in absolute poverty reduction, but the rate of decline remains slow and vulnerable to shocks. Second, the first and second derivative analyses successfully identified a critical point in the 2023-2024 period, when the rate of decline reversed to an increase accompanied by a worrying acceleration (+0.64). This finding indicates that the positive momentum for poverty alleviation is weakening and requires immediate policy correction. Third, projections through 2030 indicate that if the upward trend is not immediately stemmed through aggressive, targeted, and area-based interventions, the SDG Goal 1 target for Jayapura Regency is at risk of being missed. The discrete differential calculus approach has proven to be a useful analytical tool for detecting changes in momentum and critical anomalies often hidden behind annual data, and is therefore recommended for adoption in the ongoing monitoring and evaluation of poverty alleviation policies.

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